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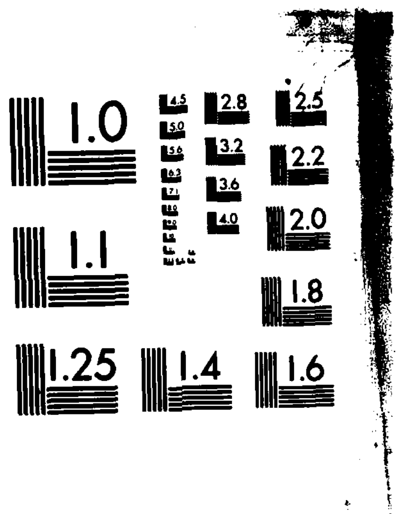

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OPTICAL FIBER LIGHTGUIDE SENSING FOR GIMBAL PICKOFFS

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U.S. ARMY MISSILE COMMAND
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Optical Fiber Lightguide
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pickoff performance
half-light reference position
sensor

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The application of optical fiber lightguides in gimbal pickoffs is under study by the US Army Missile Command. Laser diodes or light-emitting diodes, optical fibers, and solid-state light detectors can save space and weight in inertial-guidance systems for missiles and projectiles. Because they are non-contacting and have no moving parts, optical components are free of friction, gimbal-wiring, slip ring torques, potentiometer-wiper lift-off during flight, and noise. The sensors and optical fibers may also reduce manufacturing costs.

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20. ABSTRACT (Continued)

The study recommends that the concept use the pulse-duration-modulation design as an inner-gimbal wide-angle position sensor, described in Report No. T-79-81. For the outer gimbal, the light intensity concept, as described in this report, is proposed as a wide-angle position sensor. This concept provides a linear range of ±35 degrees with a nonlinear repeatable range up to ± 90 degrees.

CONTENTS

I. INTRODUCTION

The optical fiber lightguide pickoff concept relates to the development of a low cost stabilized inertial gimbal for supporting millimeter wave, imaging infrared or television sensors. The objectives of this task are cost reduction, consideration of improved materials, and improved fabrication and assembly methods.

The gimbal concept comprises an arrangement in which the torquer and the pickoff components for both the outer gimbal and the inner gimbal are mounted on the frame, leaving maximum space within the gimbals for a sensor and achieving a desirable low inertial gimbal configuration.

For a better understanding of the inertial gimbal concept, its advantages, and objects, reference should be made to Figure 1. A sensor is shown to have a line of sight or longitudinal axis (1) and is rigidly mounted in an inner gimbal (2), which is connected to an outer gimbal (3) by ball bearings for rotation about an axis (4) orthogonal to the longitudinal axis. The outer gimbal is connected to a frame (5) by ball bearings for rotation about an axis (6) orthogonal to axes 1 and 4 at a common point. Angular measurement components including torquers and position pickoff sensors are mounted in frame (5). The gyro rotor (7), Figure 2, is supported on the inner gimbal by a pair of standard angular contact preloaded duplex ball bearings.

The torquing concept uses the thrust of sonic nozzles (8) to establish the desired inertial frame of reference. The reaction force applied to the inner gimbal gives the gyroscopic element the capability of tracking a target. A sensor (1) carried by the inner gimbal provides the logic which identifies and activates the appropriate nozzle or nozzles of the torquer to generate the required tracking force. United States Patent No. 4,291,849 and Technical Report T-79-75 describe the operation of the torquer.

The position pickoff sensor is utilized to indicate changes in angular position between the stabilized inertial reference and the gimbal frame. Typical of such a system is a moving vehicle or missile following a preselected path. Attitude deviations of the vehicle from the path may be sensed by a stabilized gimbal system within the vehicle.

Pickoffs associated with the stabilized gimbal system provide output signals indicating the attitude change and the correction needed for the vehicle to restore itself to the path. Prior art pickoffs have often involved some degree of mechanical coupling between the stabilized and unstabilized components. The fiber optic lightguide pickoff eliminates these undesirable mechanical and electromagnetic torques.

II. FIBEROPTIC LIGHTGUIDE PICKOFF DESCRIPTION

The fiberoptic lightguide pickoff for use with angular measurement systems has both good signal resolution and accuracy over a wide angle. The wide angle of operation provides a linear range of 70 degrees, with a total range of 180 degrees when the nonlinear range is included. The light source and sensors are mounted on the frame with the light source purposefully

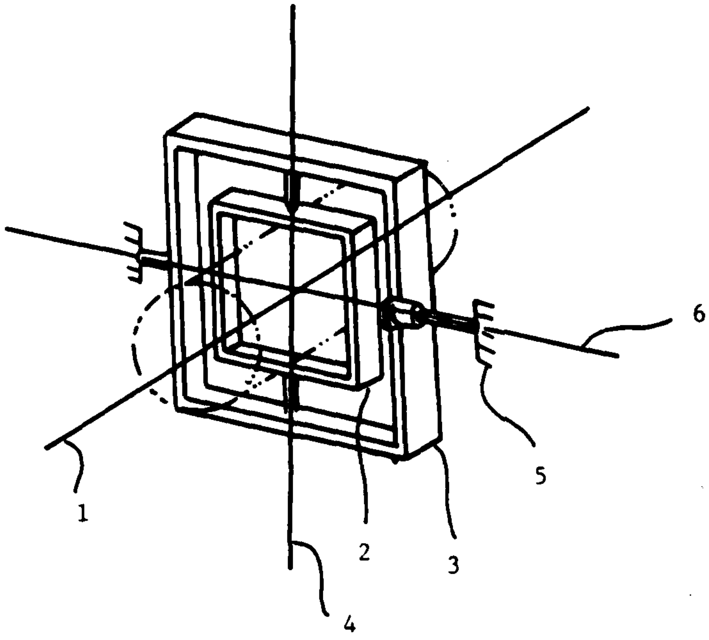

Figure 1. Gimbal concept.

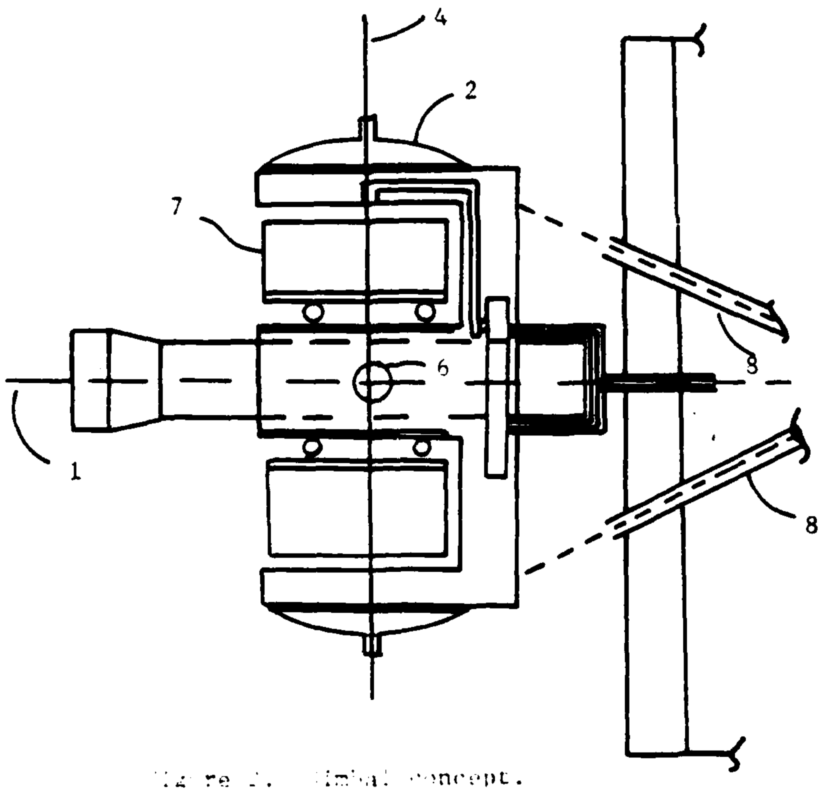

Figure 2. Gimbal concept.

misaligned with the gimbal mounted lightguide. A fiberoptic bundle is positioned on the stabilized outer gimbal structure and provides a lightguide between the light source and sensor for providing an output position change between the stabilized structure and the unstabilized frame.

Figure 3 is a plane view of a simplified, stabilized gimbal assembly with the wide angle intensity pickoff components. An unstabilized support structure (1) is adapted to be free to move in space and may typically be fixed within a missile housing. As shown in dashed lines, gimbal (2) has a fiberoptic bundle (3) which provides a lightguide from one end to the other. The particular location of the bundle on the gimbal is not critical except for the end locations. For example, the bundle may follow only one structural path as shown or may be split if desired and follow two paths from one side to the other. If a second gimbal should be attached to gimbal (2), the fiber bundle would be routed so as not to interfere with operation of the structure. The end of face (4) of bundle (3) is passed through gimbal support shaft (5) and lies off the bearing axis. The centerline of the fiber bundle is located remotely from the bearing axis centerline such that face (4) centerline is parallel with and located a distance r from the bearing centerline. The light source (6) is positioned on the unstabilized frame so that the optical emission path is at an acute angle with respect to the bearing axis. A light sensor (7) is supported by the unstabilized frame so that it lies substantially on the bearing axis opposite the light source and is coaxial with the axis or receiving light coupled through the lightguide.

Figure 4 is helpful in explaining the operation of the pickoff and shows the relationship between circular end (4) of fiberoptic bundle (3) and the bearing axis (8) to be the distance r. In this position, zero reference, no light impinges on face (4) of the lightguide.

Starting at the referenced 0° (minimum of light) on circle (10), a series of arc's are shown at 10° intervals around the circumference of the circle through 180°. As the unstabilized frame is rotated about gimbal bearing axis (8), the center of light spot (9) follows the path identified on circle (10), thus moving the spot in a circular path around axis (8) so that the light spot gradually enters the light guide at face (4) eventually completely overlapping face (4) of bundle (3) when 180° of rotation have occurred. Thus, a minimum of light passage through bundle (3) occurs at 0° and a maximum at 180° as shown in Figure 4.

To provide linear angular deviation sensing in both clockwise and counterclockwise directions for a given plane of rotation, it is necessary that the light spot be positioned initially so that approximately half of the total light emitted is coupled through the lightguide to sensor (7). This half-light position is the gimbal caged position.

III. PICKOFF EVALUATION

A. Objective

The objective of this evaluation is to experimentally determine the pickoff input angular ranges of linear output, drift coefficients, and resolution. The gimbal pickoff must accurately indicate the angular position of the stabilized sensor's line of sight with respect to rotation about the

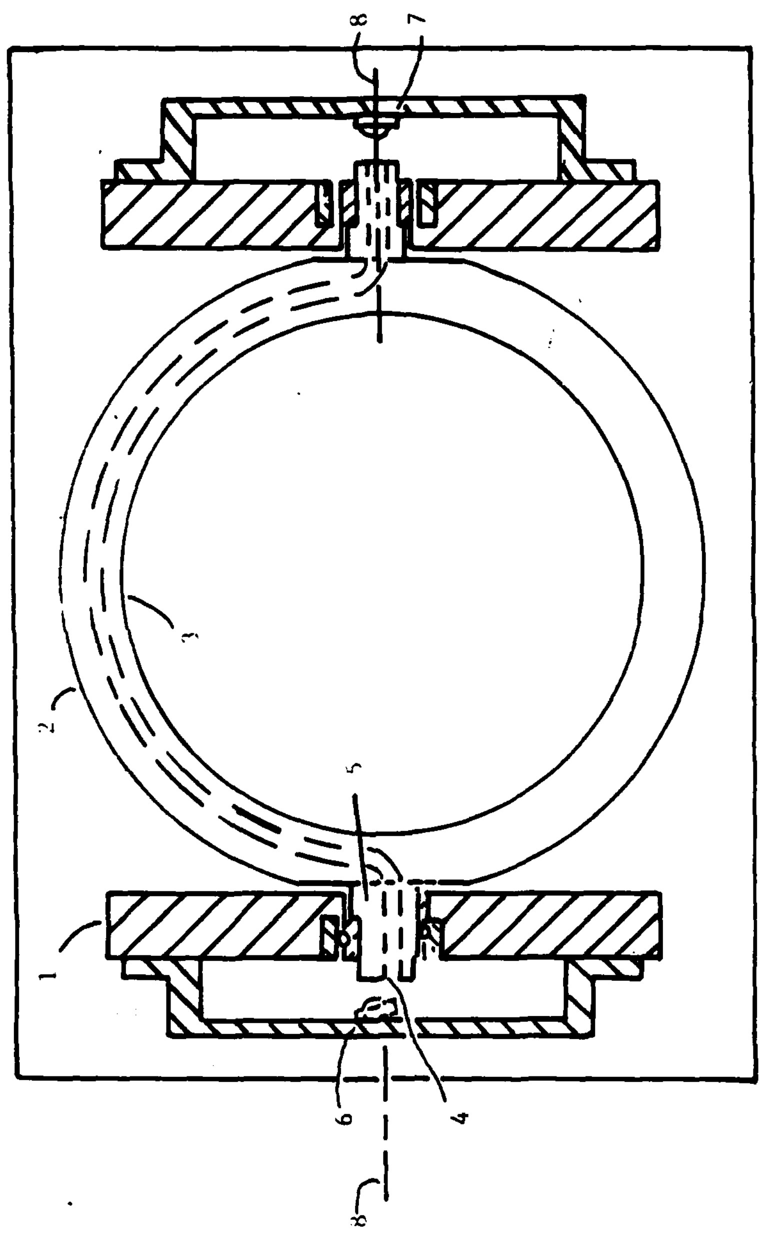

Figure 3. Fiberoptic pickoff concept.

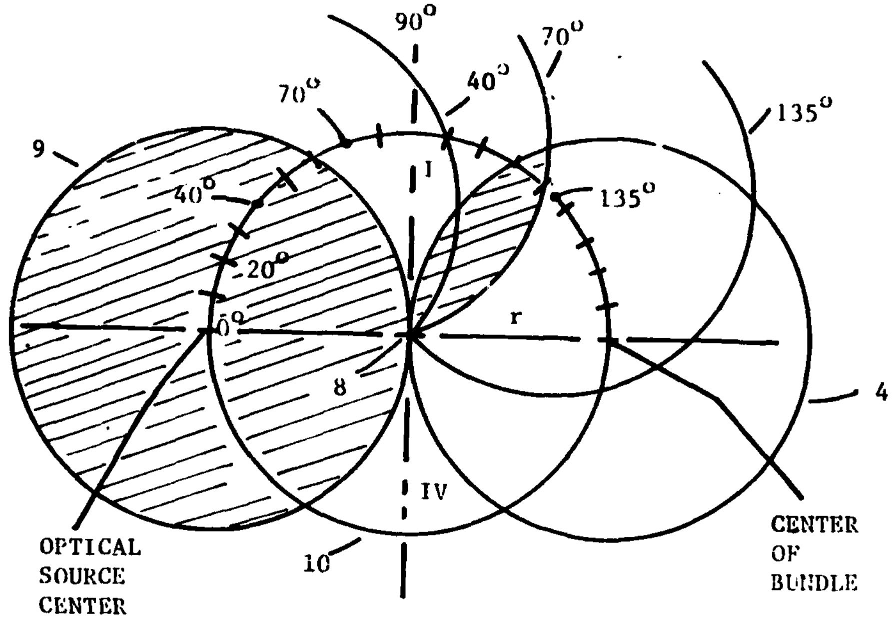

Figure 4. Operation of the pickoff.

angular freedom reference axis over a specified magnitude of angular ranges of the pickoff from its nominal null (caged) position. The pickoff input angular ranges of linear output are measured in degrees and are less than the corresponding angular freedom ranges.

B. Test Setup and Procedure

A fiberoptic lightguide pickoff apparatus as shown in Figure 3, was mounted on a flat surface table. With the gimbal in the initial half-light reference position, the pickoff electrical voltage was recorded on a chart strip. A torquer was used to rotate the gimbal in incremental steps about its axis of rotation in the positive angular displacement direction until the limit of the positive angular freedom range of the gimbal was reached. The gimbal direction was then reversed, and rotated in the negative angular displacement direction through the initial reference position and continued until the limit of the negative angular freedom range of the gimbal was reached. The gimbal direction was reversed and rotated in the positive angular displacement direction until the gimbal initial reference position was reached, and stopped on that point. The test cycle was repeated numerous times and for several lightguide bundle sizes.

The pickoff drift coefficient was measured as a function of time with the gimbal in a stationary attitude. In this test, the deviation of the output signal from an initial reference position was recorded at the end of a 20-minute elapsed time interval. This deviation was converted to an angle using the pickoff design scale factor. The largest value obtained from several repeated tests was considered the maximum drift under static conditions.

The resolution was measured for inputs greater than the threshold which produced a change in output equal to at least 50 percent of the change in output expected using the nominal scale factor.

C. Test Results

Figure 5 is a plot of the pickoff signal output as a function of gimbal displacement angle. The line is a plot of the pickoff design scale factor. The maximum observed deviation (composite error) of the output from this line is 5 percent full scale for a 70 degree input span. For ± 28 degrees, the composite error is 1 percent full scale. The pickoff free drift coefficient is less than $0.3^{\circ}/\mathrm{hr}$ and the pickoff resolution is less than 0.02 degrees.

IV. CONCLUSIONS

Although the analysis and evaluation are preliminary, some favorable conclusions can be drawn:

A. Angular measurements over a wide input span are feasible.

B. Good linearity, low noise, and low drift coefficients appear quite feasible within the low cost stabilized gimbal seeker requirements.

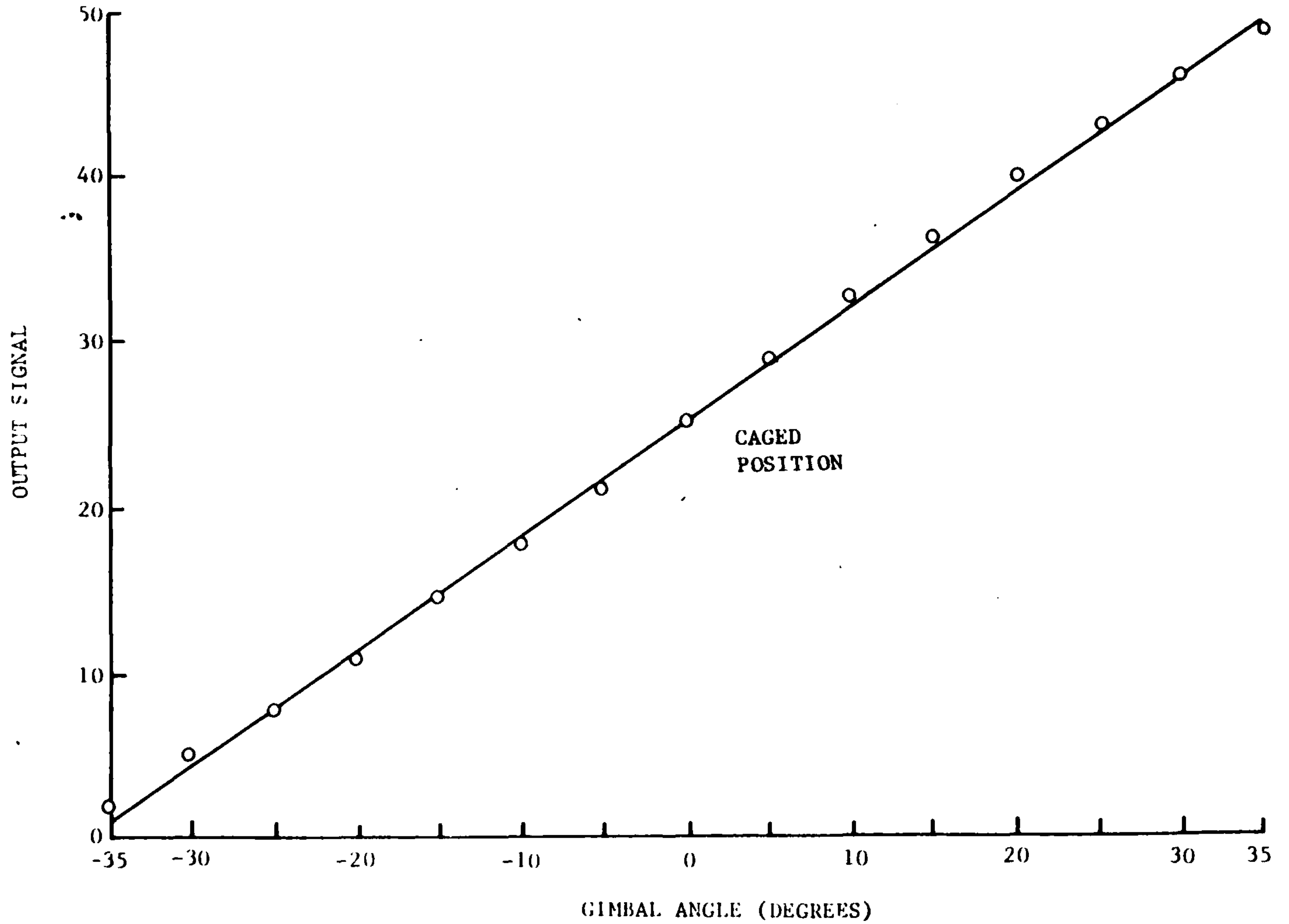

Figure 5. Pickoff scale factor.

C. The fiberoptic lightguide gimbal pickoff requires a minimum of low-cost components. A low power light emitting diode or transistor such as the Motorola MFOE 100 or 200 can function as the light source. A spectral response matched phototransistor such as the MFOD 200 can function as the sensor. A high loss fiberoptic bundle can provide the coupling for a low-cost illumination gimbal pickoff. Signal resolution of 0.02 degrees and less have been achieved with these low-cost components.

D. The wide angle fiberoptic lightguide pickoff allows accurate use of an optical system without the restrictive requirements of polarization optics, analyzers, and slip rings. It is also insensitive to electromagnetic energy interference. Fiberoptics are completely non-inductive and non-capacitive thus shielding and filtering are eliminated.

E. The absence of gimbal mounted pickoff components yields a very attractive and simple low cost pickoff concept. The preliminary test results suggest that the performance is adequate for low cost inertiai seeker applications.

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